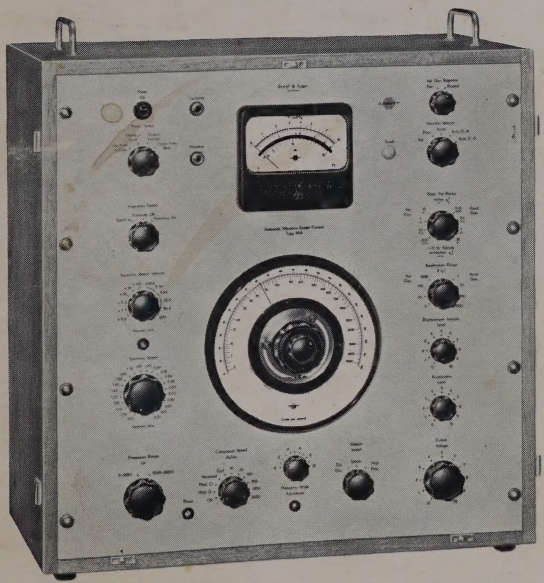
1019

INSTRUCTIONS AND APPLICATIONS

Automatic Vibration Exciter Control Type 1019



The Automatic Vibration Exciter Control is a specially designed signal source for the vibration testing of mechanical and electro-mechanical components in the frequency range 5 c/s to 10 kc/s.

- Accelerometers
- Acoustic Standing Wave Apparatus
- Artificial Ears
- Artificial Voices
- Audio Frequency Response Tracers
- Audio Frequency Spectrometers
- Audio Frequency Vacuum-Tube Voltmeters
- Automatic A. F. Response and Spectrum Recorders
- Automatic Vibration-Exciter Control Generators
- Band-Pass Filter Sets
- Beat Frequency Oscillators
- Complex Modulus Apparatus
- Condenser Microphones
- Deviation Bridges
- Distortion Measuring Bridges
- Frequency Analyzers
- Frequency Measuring Bridges
- Hearing Aid Test Apparatus
- Heterodyne Voltmeters
- Level Recorders
- Megohmmeters
- Microphone Accessories
- Microphone Amplifiers
- Microphone Calibration Apparatus
- Mobile Laboratories
- Noise Generators
- Noise Limit Indicators
- Pistonphones
- Polar Diagram Recorders
- Preamplifiers
- Precision Sound Level Meters
- Recording Paper
- Strain Gage Apparatus and Accessories
- Surface Roughness Meters
- Variable Frequency Rejection Filters
- VHF-Converters
- Vibration Pick-ups
- Vibration Pick-up Preamplifiers
- Wide Range Vacuum Tube Voltmeters

BRÜEL & KJÆR

Nærum, Denmark . ☎ 80 05 00 . ✉ BRUKJA, Copenhagen . Telex: 5316

Automatic Vibration Exciter Control

Type 1019

JUNE 1963

Contents

1. Purpose 3
2. Description 6
2.1. Oscillator 6
2.2. Automatic Frequency Scan 7
2.3. Vibration Derivation 7
2.4. Compressor Arrangement 8
2.5. Meter Section 9
2.6. Frequency Calibration 9
2.7. Remote Control 9
2.8. Parallel Operation of Generators 10
3. Control Knobs, Terminals etc. 11
4. Operation as Vibration Meter 21
4.1. Setting to Mains Voltage 21
4.2. With a Velocity Pick-up 21
4.3. With an Accelerometer 22
5. Operation as Shaker Control 24
5.1. Calibration of Frequency Scale 24
5.2. Adjustment of Automatic Frequency Scanning Range 24
5.3. Uni-directional Frequency Scanning 25
5.4. Partial Blocking of Frequency Scale Range 26
5.5. Setting of Scanning Speed 28
5.6. Setting Regulation Speed 28
5.7. Possibilities 29
5.8. Setting Auto Cross-Over Frequency 30
5.9 Summary of Preparatory Operations 30
5.10. Operation Schemes 31
6. Operation with Level Recorder 35
6.1. Possibilities 35
6.2. Synchronization with Level Recorder 35
6.3. Monitoring Shaker Table Motion 38
6.4. Plotting System Frequency Response 39
6.5. Recording Specimen Vibration 41
6.6. Recording Two Quantities Simultaneously 42
7. Remote Control Facilities 44
7.1. Start and Stop of Frequency Scan 44
7.2. Forward and Reverse Frequency Scan 44
7.3. Stand by 44
7.4. Changing Scanning Speed 44
8. Master-Slave System 46
8.1. Principle 46
8.2. Interconnections 47
8.3. Setting Up 48
8.4. Adjusting Individual Vibrations (Level and Phase) 49
8.5. Command of the System 49
Specification 50

1. Purpose

The importance of laboratory tests which can simulate the rigorous vibrations to which components and structures may be subject during service has now been fully recognised. Depending on environmental conditions it is usual to choose one (or more) of the following three types of excitation for these tests; viz.

Shock
Random motion
Sinusoidal motion

Whilst it is true that the first two are of great value in the fields of aeronautics and space technology, there is no doubt that the sine test, and preferably a sine test which sweeps throughout the frequency range of interest, is of most universal application. The design engineer has come to regard it as a day-to-day tool for determining the natural frequencies and Q values of resonances, and the life-test engineer uses such tests as the basis of his work.

Brüel & Kjær have been manufacturing sweep sine generators for several years. Type 1018 has been accepted the world over; Type 1019 which replaces it uses exactly the same fundamental principles but embodies certain refinements.

The Automatic Vibration Exciter Control feeds a shaker table, usually via a power amplifier, and the frequency of excitation is altered by means of a built-in drive. However, owing to the uneven frequency response of the mechanical system, the power required to vibrate the test object at a given

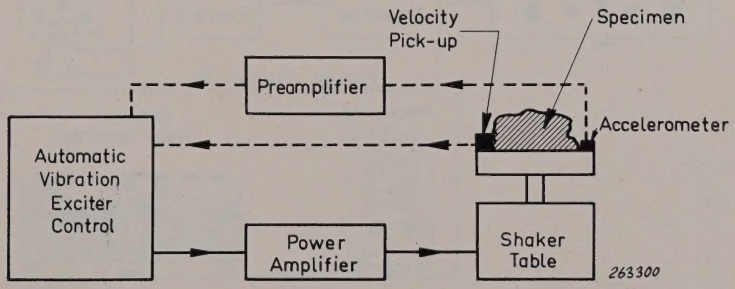


Fig. 1.1. Principle of a closed loop vibration test system. The accelerometer and velocity pick-up are alternative transducers, only the former requiring a preamplifier.

level is dependent on frequency. To keep the vibration level constant whatever the frequency, a signal measuring the motion of the shaker table is fed back to the Automatic Vibration Exciter Control. This completes a servo loop which regulates the power output of the exciter so that various predetermined test programmes can be carried out under controlled conditions. Either an accelerometer or a velocity pick-up may be used as transducer and the vibration derivation section of the 1019 contains all the integrator and differentiator networks necessary for deriving acceleration, velocity, or displacement from either input. It is possible to hold any of these dynamic properties constant on the shaker table, and also there are two "auto" arrangements in which the quantity measured and controlled can be changed at a predetermined "cross-over" frequency, i.e.

displacement below cross-over to acceleration above,
or velocity below cross-over to acceleration above.

All the vibration derivatives can be read directly on the semi-logarithmic meter scale provided the velocity or acceleration signals to the inputs are scaled to 96.3 mV per inch/sec or 10 mV per g respectively. Acceleration generators should be used in conjunction with the Accelerometer Preamplifier Type 2620. This preamplifier has graduated sensitivity controls, by means of which the sensitivity of the preamplifier is set in relation to the known sensitivity of the accelerometer so as to obtain exactly 10 mV/g for the 1019's input.

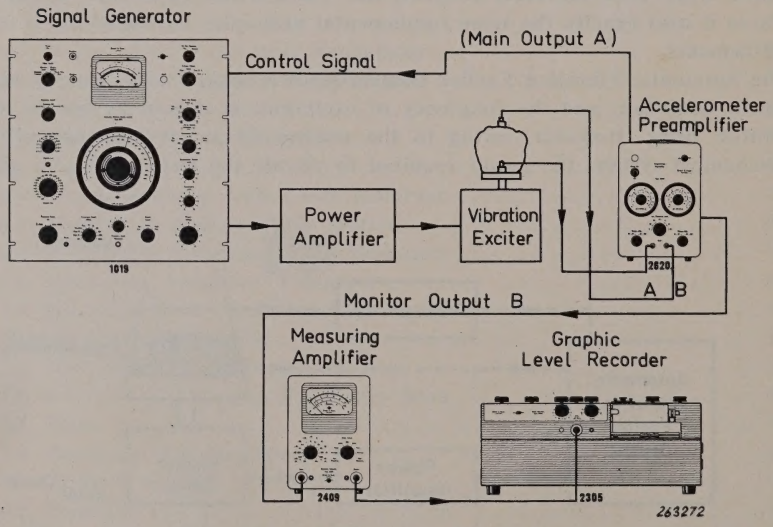


Fig. 1.2. Fundamentals of a vibration test set-up utilizing the Automatic Vibration Exciter Control Type 1019.

It is often of interest to obtain a graphical plot of the response of vibrated specimens. This is conveniently achieved by synchronizing the frequency scan of the 1019 with the frequency graduations on chart paper running through a Brüel & Kjær Level Recorder Type 2305.

One Automatic Vibration Exciter Control can be set up as a "master" to control up to three similar "slave" units. In such an arrangement the "master" controls its own shaker table as well as the frequency of the output signal from the "slaves". Each "slave", however, can control the vibration level of its associated shaker. It is thus possible to synchronize the movement of up to 4 vibration exciters for the testing of large specimens. Furthermore, the phase relationship between the "master" and "slave" output signal can be adjusted over a full 360° angle.

The Automatic Vibration Exciter Control Type 1019 (cabinet version) can also be supplied for standard 19″ rack mounting as Type 1039.

2. Description

The principle of operation is illustrated in the block diagram Fig. 2.1.

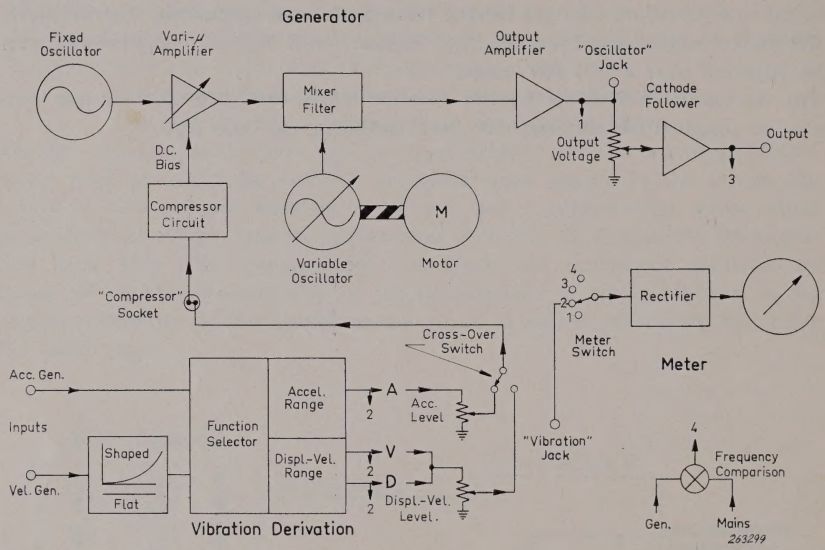


Fig. 2.1. Principle of the Automatic Vibration Exciter Control.

2.1. Oscillator.

The oscillator works on the heterodyne principle; by beating together two comparatively high frequencies—one from a variable and one from a fixed oscillator—an output frequency of between 5 and 10000 c/s is produced. The fixed oscillator oscillates at either 30 kc/s or 35 kc/s, depending on the setting of FREQUENCY RANGE. The variable oscillator frequency is between 25 kc/s and 30 kc/s, as determined by the position of the main tuning capacitor. There are therefore two frequency ranges, viz.

5—5000 c/s
or 5005—10000 c/s

The first, which is covered in a true logarithmic sweep, is marked directly on the large circular scale. The second range is not logarithmic, the frequency being reckoned by adding 5000 c/s to the scale reading.

2.2. Automatic Frequency Scan.

The frequency range can be continuously scanned with various speeds by a built-in synchronous motor which can be reversed electrically. The motor speed can be changed in six coarse steps, covering the range 0.3 to 100 degrees/min. Within each of the six steps the speed can be fine adjusted in 22 steps. Using both controls provided, there are 132 possible scanning speeds from 0.3 to 300 degrees/min.*)

The frequency range for to-and-fro scanning is easily adjusted. Unidirectional scanning throughout 360° is also possible, the output being cut dead while the pointer is on the blank part of the dial, and, if the scanning range is to be reduced, while on the unwanted sectors of the scale.

2.3. Vibration Derivation.

The input signal, which can be from either an accelerometer or a velocity pick-up, is processed according to the following table, depending on which quantity has been selected by FUNCTION SELECTOR.

Table I.
Frequency-weighting in the vibration derivation section.

Input \ To read	Acceleration	Velocity	Displacement
Acceleration	Direct	— 6 dB/Oct.	— 12 dB/Oct.
Velocity	+ 6 dB/Oct.	Direct	— 6 dB/Oct.

Note: Differentiation; Equivalent to slope + 6 dB/Oct.
Integration; Equivalent to slope — 6 dB/Oct.

Considerable low-frequency noise is inherent in any measuring system involving integration, so special networks (which do not affect the measurements) are included to reduce this and to prevent the whole system from "hunting".**)

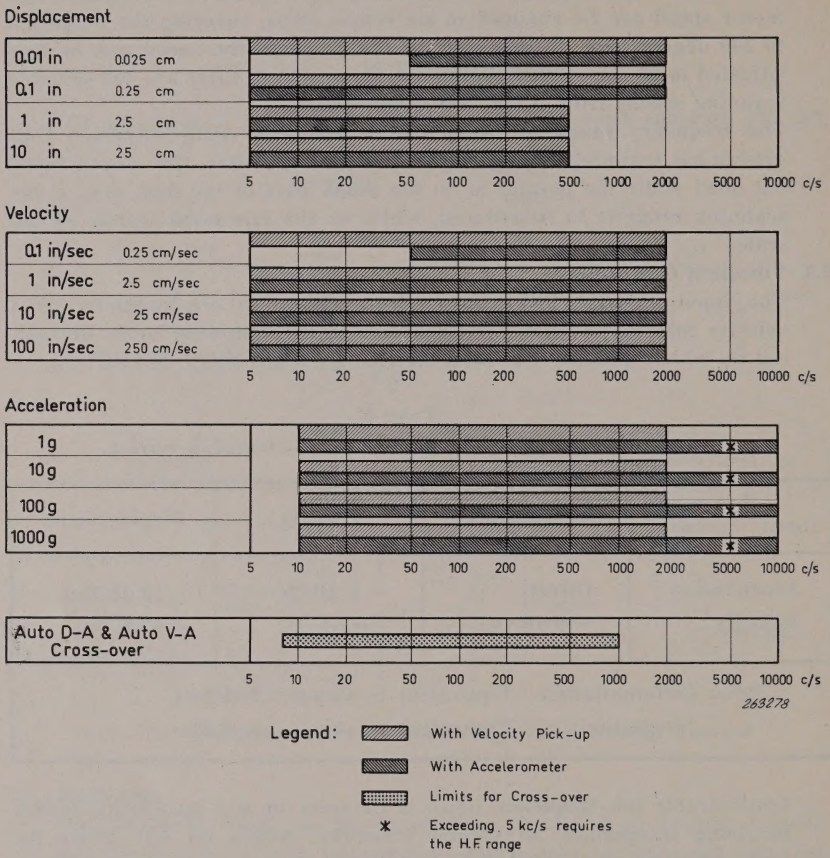
In the two "Auto" positions of FUNCTION SELECTOR the relays governing which weighting function is effective at a given instant are switched at a predetermined generator frequency, adjustable between 8 and 1000 c/s.

The acceptable ranges for measurement and control are given on p. 8.

*) Additionally there are six other scanning speeds suitable for achieving synchronism with the frequency-calibrated-paper transport on the Brüel & Kjær Level Recorder Type 2305.

**) This is a low frequency system oscillation which might otherwise occur when the generator frequency is a few thousand cps.

Table II.
Frequency Ranges for Measurement and Control.


Displacement
0.01 in 0.025 cm
0.1 in 0.25 cm
1 in 2.5 cm
10 in 25 cm
5 10 20 50 100 200 500 1000 2000 5000 10000 c/s
Velocity
0.1 in/sec 0.25 cm/sec
1 in/sec 2.5 cm/sec
10 in/sec 25 cm/sec
100 in/sec 250 cm/sec
5 10 20 50 100 200 500 1000 2000 5000 10000 c/s
Acceleration
1 g
10 g
100 g
1000 g
5 10 20 50 100 200 500 1000 2000 5000 10000 c/s
Auto D-A & Auto V-A Cross-over
5 10 20 50 100 200 500 1000 2000 5000 10000 c/s
263278
Legend:
With Velocity Pick-up
With Accelerometer
Limits for Cross-over
Exceeding 5 kc/s requires the H.F range

2.4. Compressor Arrangement.

Except when the COMPRESSOR SPEED switch is "Off",*) the vibration signal is fed to the regulation ("compressor") circuits. Here it is rectified and the resulting DC is used to bias a variable-μ stage in the generator. Thus, if the shaker table vibration becomes too great, a larger bias signal appears and the oscillator output drops until the status quo is regained. The integration time constant in the circuit which filters the rectified control signal is very important since it determines the

*) The open-loop output voltage from the generator rises 10 dB as soon as COMPRESSOR SPEED is moved away from "Off".

speed with which a sudden change at the shaker table is regulated back to "normal". The various positions of COMPRESSOR SPEED offer a choice of regulation rates and these are discussed in the next chapter (under COMPRESSOR SPEED knob).
In the "Stand by" condition of OPERATION SWITCH and, after suitable setting,*) over unwanted sectors of the frequency scale, a cut-off bias is routed through the compressor to kill the generator output.

2.5. Meter Section.

The moving coil meter which is fully protected against overload is calibrated to read peak acceleration or velocity and peak-to-peak displacement. Instead of reading vibration level it can be switched to read the r.m.s. output voltage from the generator or the level before the output cathode follower. In the latter case METER SWITCH is on "Oscillator Voltage"; when the built-in generator is employed this position is useful for checking the drive level while setting up, and when the OUTPUT SWITCH is on "Ext. Osc." the meter then reads the level of the signals injected into the OSCILLATOR jack.
A fourth position of METER SWITCH is "Power Frequency Beat", the purpose of which will now be explained.

2.6. Frequency Calibration.

The generator is frequency calibrated by checking two points on the frequency scale against a well defined frequency. The reference frequency is that of the mains supply which is compared first to the fundamental and then to the fifth harmonic of the generator signal. This fifth harmonic is obtained by feeding part of the generator signal through a network causing heavy non-linear distortion. When the generator is correctly set to the fundamental of the mains supply frequency a zero beat appears on the indicating meter. Fine calibration can be made in a similar way at one fifth of the mains frequency. Any necessary adjustment of the generator frequency is made by a separate control, changing the frequency of the variable oscillator.

2.7. Remote Control.

Various functions of the Automatic Vibration Exciter Control can be remotely controlled. The most important are: —

1. Start and Stop of automatic frequency scan. This is particularly useful when frequency response curves of vibrated specimens are to be plotted on a B & K Level Recorder Type 2305.
2. Stand by, which is a condition of the generator where the output voltage is suppressed by the compressor.

These, and other remote control facilities, are fully covered in Chapter 7.

*) For details on partial blocking of the frequency scale see section 5.4.

2.8. Parallel Operation of Generators.

When driving two or more complete vibration systems in parallel, the fixed and variable oscillators in one Automatic Vibration Exciter Control (the "master" unit) are used to feed the mixers in all the other ("slave") units. Associated with each mixer there is a PHASE control which can be positioned so that the outputs, though all the same frequency, can be adjusted in phase relative to one another.

The various compressor systems are separate so that by adjusting the vibration LEVEL controls individually, the levels at each shaker need not be equal. However, since COMPRESSOR SPEED is normally set so that the regulation speed is programmed as a function of frequency,*) it is the switching on the "master" unit which governs the regulation speeds of all units.

Full details about the setting up are given in Chapter 8.

*) See information concerning COMPRESSOR SPEED in Chapter 3.

3. Control knobs, terminals etc.

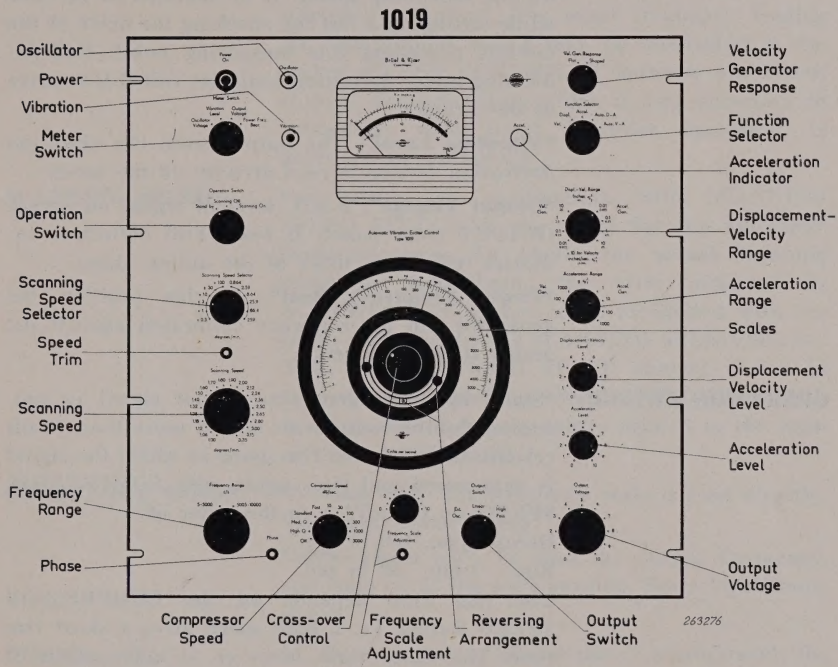


Fig. 3.1. Front panel.

Front Panel (Fig. 3.1)

OSCILLATOR: Telephone jack for connecting a stroboscope to detect resonance points on the specimen, checking of the oscillator wave form, or monitoring the voltage. With OUTPUT SWITCH in position "Ext. Osc." a tape recorder or an external oscillator can be connected to the cathode-follower output stage of the instrument. The input impedance of the OSCILLATOR terminals is 100 kΩ.

POWER: To switch the power on and off for the complete apparatus. When switched on the indicating meter and frequency scales are illuminated.

VIBRATION: Telephone jack for checking and monitoring the vibration level, e.g. by means of a Level Recorder (Chapter 6) or a cathode-ray oscilloscope.

METER SWITCH: **"Oscillator Voltage".** The R.M.S. signal level at the point before the OUTPUT VOLTAGE attenuator, i.e. at the front panel jack OSCILLATOR, is read on the indicating meter. It is intended to be used while setting-up a test for checking the drive of the circuits preceding this measuring point. Full indicating meter deflection indicates full R.M.S. drive of the circuits.

"Vibration Level". The output from the vibration derivation section is read directly on the meter.

"Output Voltage". R.M.S. level of signal on socket OUTPUT (rear panel) is read. Full deflection indicates full R.M.S. drive of the output stage.

"Power Frequency Beat". In this position the generator can be frequency calibrated against the mains supply frequency.

OPERATION SWITCH: **"Stand by".** The generator output signal is suppressed by the compressor circuit more than 70 dB relative to full drive. The speed at which the signal is suppressed and rises again with COMPRESSOR SPEED set to "off" is in the order of:
Decay time, 150 m sec.
Rise time, 30 m sec.
The rise time depends on the COMPRESSOR SPEED setting, i.e. a high speed gives a short rise time. The decay time, however, is independent of COMPRESSOR SPEED setting and has the value given above.

"Scanning Off". The automatic frequency scanning drive is stopped instantaneously.

"Scanning On". The automatic frequency scanning drive is started instantaneously.

SCANNING SPEED SELECTOR: **"× o.3", "× 1", "× 3", "× 10", "× 30" and "× 100"** are factors by which the degrees/min. value indicated on the SCANNING SPEED control should be multiplied. The product gives the actual scanning speed of the frequency pointer in degrees/min. The values given for the further six clockwise posi-

tions of the knob indicate the speeds available when the Brüel & Kjær Level Recorder Type 2305 is used in conjunction with the Automatic Vibration Exciter Control (Chapter 6). When set to one of these six speeds the SCANNING SPEED control is automatically switched out of circuit.

SPEED TRIM: The motor speed can be fine adjusted by this screwdriver control. The exact frequency feeding the synchronous motor may be monitored at the socket SWEEP CONTROL B between pin 3 and chassis. The procedure, which is only necessary in connection with Level Recorder operation, is described in section 6.2.

SCANNING SPEED: For setting, in combination with SCANNING SPEED SELECTOR, the speed for the automatic frequency scan. To obtain the actual scanning speed in degrees/min., the value indicated by SCANNING SPEED has to be multiplied with the factor indicated by the SCANNING SPEED SELECTOR. The SCANNING SPEED control is not in operation when the SCANNING SPEED SELECTOR is set to one of the six values printed to the right of this control knob.

FREQUENCY RANGE: **"5—5ooo c/s".** The frequency scale is read directly. True logarithmic sweep.

"5005—10ooo c/s". To find the output frequency, add 5ooo c/s to the scale reading. Not a logarithmic sweep.

PHASE: In, for example, a "master-slave" arrangement, the phase between the individual generator outputs can be adjusted. The phase shifting range covered by this control is approximately 150°.

COMPRESSOR SPEED: For setting the regulation speed of the compressor arrangement.

"10", "30", "100"....."3ooo" indicate fixed regulation speeds in dB/sec. which do not change as a function of frequency.

"High Q", "Med. Q", "Standard" and **"Fast"** refer to different programmed changes in regulation speed, made as a function of frequency. The speed is altered step-wise to the various values, and at the frequencies, given in the table below.

Table III

COMPRESSOR SPEED position	Change-over frequency (c/s)				
	30	100	300	1ooo	
"Fast"	30	100	300	1ooo	3ooo dB/sec.
"Standard"	10	30	100	300	1ooo dB/sec.
"Med. Q"	10	10	30	100	300 dB/sec.
"High Q"	10	10	10	30	100 dB/sec.

Cross-Over Control: Of interest when using "Auto D-A" or "Auto V-A" positions of FUNCTION SELECTOR. Turning the small knob relative to the large one alters the cross-over frequency. (Limits 8 c/s to 1ooo c/s).

FREQUENCY SCALE ADJUSTMENT: For frequency calibration of the generator; changes the frequency of the variable oscillator. The screw-driver operated control is for coarse adjustment in case the range of the fine adjustment knob is not sufficient.

Reversing Arrangement: The arm, when hit by the sweep stops, causes the sweep motor to change direction. Must be in place for to-and-fro scanning but must be removed for continuous uni-directional scanning.
The two knurled set screws are positioned in their slot so as to flick the reversing arm at the chosen limits of scan.

OUTPUT SWITCH: **"Ext. Osc.".** The internal generator is disconnected so that no signal is present at the output.
An external oscillator can then be connected to the OSCILLATOR jack on the front panel.
"Linear". The amplitude-frequency characteristic of the generator is flat, i.e. independent of frequency.
"High Pass". The lower part of the frequency range is attenuated by a high-pass filter. The limiting frequency is 30 c/s and the maximum slope is 6 dB/octave below this frequency. Useful for constant displacement operation at low frequencies.

OUTPUT VOLTAGE: Continuously variable potentiometer, located immediately following the OSCILLATOR terminal.

ACCELERATION LEVEL: Potentiometer to control the acceleration level of the shaker in conjunction with FUNCTION SE-

LECTOR and ACCELERATION RANGE. The level can be read off the instrument meter when the METER SWITCH is in position "Vibration Level".

DISPLACEMENT-VELOCITY LEVEL: Potentiometer which controls the displacement level or the velocity level of the vibration exciter, the type of control being dependent upon the positions of FUNCTION SELECTOR and DISPLACEMENT-VELOCITY RANGE. With METER SWITCH in position "Vibration Level" the actual vibration level can be read off the instrument meter.

Scales: **Inner scale:** Frequency in c/s.
Logarithmic (read directly) for "5—5000 c/s" setting of FREQUENCY RANGE. Add 5000 c/s to pointer indication when using "5005—10000 c/s" range.
Outer scale: Linear in degrees angle.

ACCELERATION RANGE: For choosing a suitable acceleration range (values in peak g) allowing easy reading of the meter. Use the left-hand positions if the control transducer is a velocity pick-up, and the right-hand positions if it is an accelerometer.

DISPLACEMENT-VELOCITY RANGE: Whether it is displacement or velocity that is in question depends on the setting of FUNCTION SELECTOR.
Large figures: inches peak-to-peak displacement.
Small figures: centimetres peak-to-peak displacement.
For velocity readings, the full-scale values are 10 times the numbers shown and are single peak.
When a velocity pick-up is used as transducer, set to one of the left-hand positions. With an accelerometer, set to one of the right-hand positions.

Acceleration Indicator: A lamp which lights whenever the derived vibration signal is acceleration. This is useful when setting the cross-over frequency in "auto" operation.

FUNCTION SELECTOR: For setting the required type of measurement or regulation. When the compressor is switched in and FUNCTION SELECTOR is on "Vel." the velocity level of the shaker table is controlled. Similarly, if on "Displ." or "Acc." the displacement or accelera-

tion levels respectively are held constant.

"Auto D-A": Constant displacement is maintained below the cross-over frequency, and constant acceleration above it.

"Auto V-A". Constant velocity is maintained below the cross-over frequency, and constant acceleration above it.

Either an accelerometer or a velocity pick-up may be used for any function, and in the case of the two "Auto" conditions, one kind of transducer may be employed below cross-over and the other kind above cross-over.

VELOCITY GENERATOR RESPONSE:

"Shaped". To compensate the frequency characteristic of MB velocity pick-ups Model 124 or 126.

"Flat". The response is flat from 5 c/s to 2000 c/s.

Back Plate (Fig. 3.2).

Note: Various pre-set controls are visible but these are not mentioned below

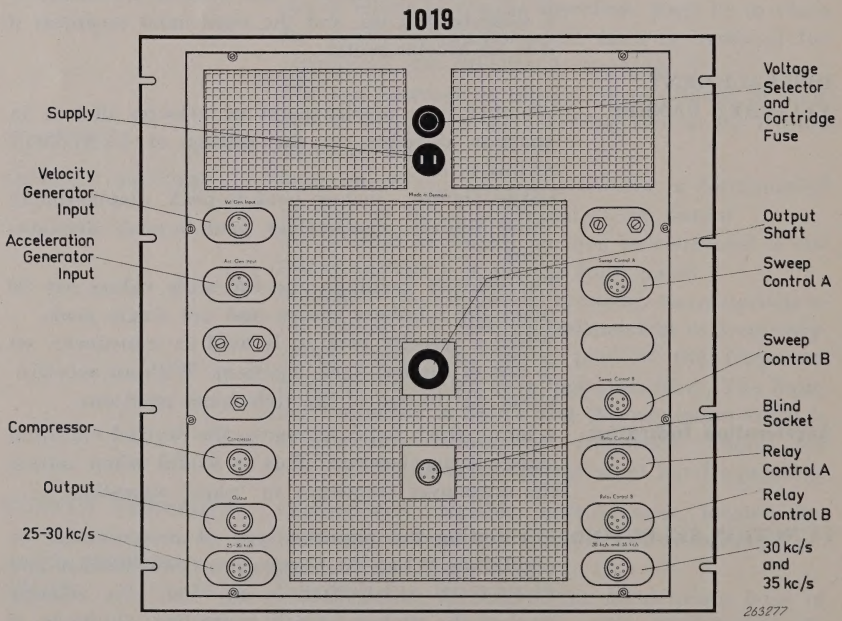
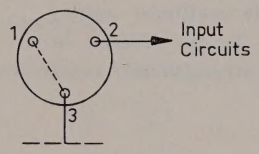


Fig. 3.2. Back plate.

and **must not be touched** without recourse to the Service Manual for Type 1019 and to proper test equipment.
The wiring shown in the accompanying diagrams is **internal.** The necessary external connections are described in the text.
Where a shorting link is shown (dashed line) this is soldered onto the inside of the socket. Such links may have to be removed when wiring up one of the special facilities. For standard procedures, however, they must be in place.

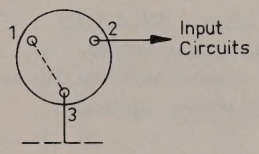
VELOCITY GENERATOR INPUT:



263285

Plug: Cannon XLR3-11C.
Pins 1 (3) and 2:
Input for direct connection to a velocity sensitive (electrodynamic) transducer which should have a sensitivity of 96.3 mV per inch/sec.
Input impedance: 200 kΩ approx.
Transducer impedance: 2ooo Ω max.

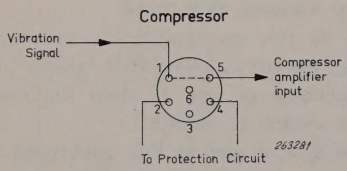
ACCELERATION GENERATOR INPUT:



263285

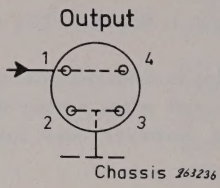
Plug: Cannon XLR3-11C.
Pins 1 (3) and 2:
Input for connection to an accelerometer via an Accelerometer Preamplifier Type 2620. The latter ensures correct signal scaling (10 mV/g) regardless of the accelerometer sensitivity.
Input impedance approximately 80 kΩ.

COMPRESSOR:



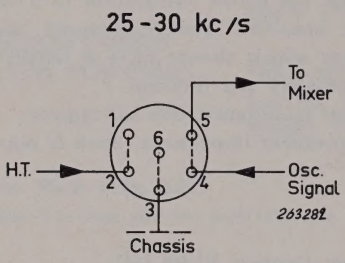
Plug: Cannon WK-6-21C.
Pin 1 and 5:
If it is desired to give the compressor circuit a particular frequency weighting, a network with the required shaping characteristic can be inserted between 1 and 5. The standard interconnection between the two pins has to be removed.
Pin 2 and 4:
Intended for connection of a system protecting circuit, which switches off the shaker power amplifier if sudden changes in the feed back voltage occur.

OUTPUT:



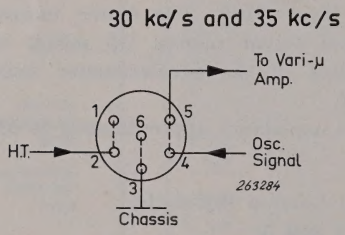
Plug: Cannon WK-4-21C.
Generator output terminal. Indicating meter measures at this terminal when METER SWITCH is in position "Output Voltage".

25—30 kc/s:



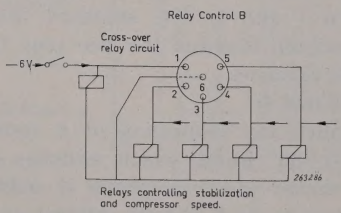
Plug: Cannon WK-6-21C.
Variable oscillator output.
Pin 5: To be utilized in a "master-slave" arrangement; see section 8.2.

30 kc/s AND 35 kc/s:



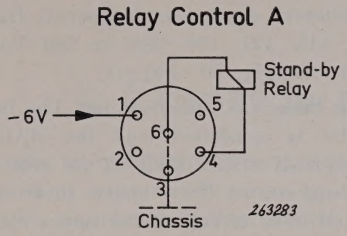
Plug: Cannon WK-6-21C.
Fixed oscillator output.
Pin 5: For connection to associated "slaves" where applicable.

RELAY CONTROL B:



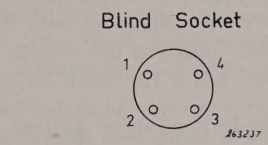
Plug: Cannon WK-6-21C.
Pin 1: For governing the cross-over relay circuit in associated "slaves". 6 V is present on pin 1 when the cross-over switch is closed.
Pins 2, 3, 4 and 5: For governing the compressor relays and stabilizing relays in associated "slaves".

RELAY CONTROL A:



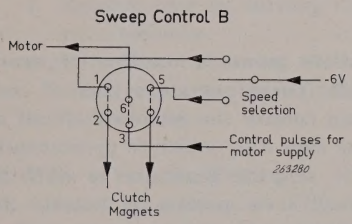
Plug: Cannon WK-6-21C.
Pin 4: For energizing the stand-by relay in associated "slaves".

BLIND SOCKET:



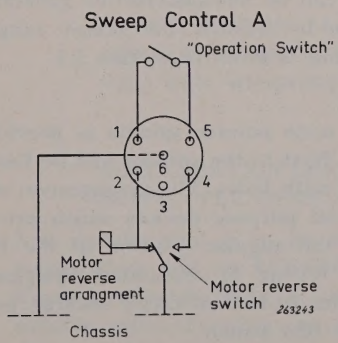
Plug: Cannon WK-4-21C.
Can be used for applying auxiliary signals or special information, for example, from the scale pointer shaft. See also "Special Purpose Arrangement" on p. 20.

SWEEP CONTROL B:



Plug: Cannon WK-6-21C.
Pin 3 and 6: Intended for remote control of motor start and stop. Further instruction is given in sections 6.2 and 7.1. Between 3 and chassis, the control signal for the motor can be monitored.
Pin 1 and 2, 4 and 5: For remote control of a gear shift arrangement in the scanning system. (Section 7.4).

SWEEP CONTROL A:



Plug: Cannon WK-6-21C.
Pin 1 and 5: For remote operation of the paper drive start and stop of a Brüel & Kjær Level Recorder Type 2305 (see section 6.2).
When OPERATION SWITCH is set to position "Scanning On" the contact between pin 1 and 5 opens.

Pin 2, 4, and 6: For remotely reversing the scanning motor.

NOTE: The arm of the motor reverse switch should be unscrewed during remote control.

Cartridge Fuse and Mains Voltage Selector: Concerning the fuse see below. The instrument can be set to operate from 100, 115, 127, 150, 220 or 240 Volts mains supply, 50—400 c/s.

Fuses: **Main Fuse.** 1.6 A medium lag. The fuse holder is combined with the MAINS VOLTAGE SELECTOR at the rear of the apparatus. Two spare fuses are placed in a holder on the upper chassis, accessible after removing the rear plate.

6 Volts DC Supply. 2.5 A normal. Protects the 6 V DC supply circuit. The fuse is of the "soldered in" variety. It is accessible from the rear of the apparatus after the rear plate has been removed, and is located on the vertical plate to the right of the capacitor unit.

On removing the rear plate, the following additional facilities may be catered for:

Adjustable Frequency Range Blocking: Three cam discs are mounted on the frequency scale pointer shaft. These operate a pair of contacts which in turn control the Stand-by circuit of the generator. One cam disc, which is permanently fixed on the shaft, sets the generator to stand-by when the frequency scale pointer is outside the frequency scale graduation. The two other discs are adjustable inside the frequency scale graduation, so that any initial or final part of the frequency range can be blocked, i.e. the generator will be on stand-by outside the preset ranges. Detailed instruction is given in section 5.4.

Special Purpose Arrangement: The end of the scale pointer spindle is provided with a 1/4″ hole. Next to the spindle will be found a mounting plate with holes. The arrangement can be used for special purpose devices which are to be governed by the angular position of the frequency pointer. Wiring to associated equipment can be led via the BLIND SOCKET located near the middle of the rear panel.

4. Operation as Vibration Meter

To take the procedure in easy stages, the simple case where the instrument is used to measure vibrations on a self-excited structure such as an engine will be considered in this chapter. The technique is not only applicable to this kind of investigation but is also an essential part of the laboratory test systems discussed in later chapters. Proper measurement is fundamental to any vibration study.

In addition to the Automatic Vibration Exciter Control, either an accelerometer and Accelerometer Preamplifier Type 2620 or alternatively a velocity pick-up will be required.

4.1. Setting to Mains Voltage.

Before connecting the 1019 (or the Preamplifier) to the mains, ensure that the voltage selector, located at the rear, is adjusted to the correct supply voltage. To readjust:

1. Remove fuse by turning centrepiece of voltage selector one quarter anti-clockwise.
2. Turn the centre ring of the selector with a coin so that the white mark points to the desired voltage.
3. Replace fuse.

4.2. With a Velocity Pick-up.

Connect the pick-up to VEL. GEN. INPUT. The pick-up should preferably have a sensitivity of 96.3 peak mV per peak inch/sec. M.B. Models 124 or 126 are satisfactory.

Set

POWER	to "On"
METER SWITCH	"Vibration Level"
OPERATION SWITCH	"Scanning Off"
VEL. GEN. RESPONSE	"Shaped", if an M.B. velocity pick-up Model 124 or 126 is used. Otherwise to "Flat"
ACCELERATION LEVEL	Fully clockwise, "10"
DISPL. - VEL. LEVEL	Fully clockwise, "10"

Now decide what is to be measured, viz. Displacement, Velocity, or Acceleration, and set FUNCTION SELECTOR accordingly.

If acceleration is to be measured, set ACCELERATION RANGE to a suitable value, choosing one of the four left hand side positions. The

reading is in peak g and the scale may be read directly provided the pick-up has a sensitivity of exactly 96.3 mV per inch/sec.
If displacement or velocity are of interest, set DISP. - VEL. RANGE to one of the four left hand side positions. The meter then reads, for 96.3 mV per inch/sec. pick-up sensitivity, peak velocity or peak-to-peak displacement. Note that the full scale *velocity* reading is ten times the figure quoted around the DISPL. - VEL. RANGE control.
The acceptable frequencies for measurement in the various ranges are given in Table II, p. 8.

4.3. With an Accelerometer.

The mounting of the accelerometer and its connection to the Accelerometer Preamplifier Type 2620 is explained in the manual for Type 2620. Take the MAIN OUTPUT of the 2620 to the ACC. GEN. INPUT of the Automatic Vibration Exciter Control.

I. Set up the Accelerometer Preamplifier:

POWER "On"

Left hand side RANGE mV/g and Calibration Potentiometer to the sensitivity (peak mV per peak g) of the accelerometer connected to INPUT A. Clamp Calibration Potentiometer in position with an Allen key. Set LOW FREQUENCY LIMIT control to the highest acceptable figure of left hand positions (refer Table II, p. 8).

Type 2620 has two channels so a second accelerometer may be connected to INPUT B and its sensitivity set on the right-hand RANGE mV/g and Calibration Potentiometer. An oscilloscope or other suitable instrument can then monitor the signal at the MONITOR OUTPUT. Alternatively, moving LOW FREQUENCY LIMIT to one of its right hand positions feeds channel B to the 1019.

Note: If a preamplifier other than Type 2620 is used, it must incorporate sharp cut-off filters to attenuate frequencies outside the range of the 1019, and also its power supplies must be scrupulously stabilized. There should be provision for rationalizing its output scaling to 10 mV/g.

II. Referring to the 1019, set

POWER	to "On"
METER SWITCH	"Vibration Level"
OPERATION SWITCH	"Scanning Off"
ACCELERATION LEVEL	Fully clockwise, "10"
DISPL. - VEL. LEVEL	Fully clockwise, "10"

Now decide what is to be measured, viz. Displacement, Velocity, or Acceleration, and set FUNCTION SELECTOR accordingly.
If acceleration is to be measured, set ACCELERATION RANGE to a suitable value, choosing one of the four right hand side positions. Read the meter scale directly in peak g.
If displacement or velocity are of interest, set DISP. - VEL. RANGE to one of the four right hand side positions. The meter then reads peak

velocity or peak-to-peak displacement. Note that the full scale **velocity** reading is ten times the figure quoted around the DISPL. - VEL. RANGE control. The acceptable frequencies for measurement in the various ranges are given in Table II, p. 8.

5. Operation as Shaker Control

The operation of part of the equipment, i.e. the part which actually measures the vibrations, has already been discussed in Chapter 4. The present chapter starts with explanations about how to operate the generator itself (also the compressor), and finishes with schemes which summarize all the manipulations.

5.1. Calibration of Frequency Scale.

Check the mains voltage selector (section 4.1) and switch POWER "On". Allow a few minutes to warm up.

Set

METER SWITCH	to "Power Freq. Beat"
OPERATION SWITCH	"Scanning Off"
FREQUENCY RANGE	"5—5ooo c/s"
COMPRESSOR SPEED	"Off"
OUTPUT SWITCH	"Linear"

Frequency scale pointer to frequency of the mains.

Turn FREQUENCY SCALE ADJUSTMENT until a beat shows up on the indicating meter. Fine adjust by same knob until beat ceases. In case the range covered by the control is insufficient, use also the coarse adjustment control (screwdriver operated).

NOTE: The meter pointer swing for a slow fluctuation may be in the order of 8 dB peak to peak.

Thereafter set frequency scale pointer to 1/5 of mains frequency. Fine adjust again by FREQUENCY SCALE ADJUSTMENT control to obtain zero beat.

NOTE: The meter pointer swing for a slow fluctuation will now be in the order of 1 dB peak to peak.

NOTE: As the described beat frequency is not present on the OUTPUT during calibration, it is possible to frequency calibrate with the complete vibration system in operation. The compressor circuit may also be in operation but if it is, a beat can be obtained only if the voltage read on the indicating meter is higher than 0.2 V with METER SWITCH in position "Oscillator Voltage".

5.2. Adjustment of Automatic Frequency Scanning Range.

a. Choose the correct setting of FREQUENCY RANGE. For the higher range, 5ooo c/s must be added to the scale reading. Note that the scale is logarithmic only for the 5—5ooo c/s range.

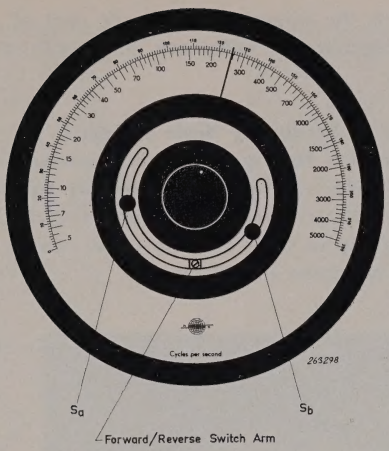


Fig. 5.1. Frequency Dial, also showing the adjustable stops for the automatic reversing mechanism.

b. Loosen the finger screw Sa and Sb on the slotted plate, Fig. 5.1.
c. Turn Frequency scale to the lower frequency limit of the range within which it is desired to scan.
d. Set reverse-switch arm, located underneath guide slot, to its left hand position.
e. Move screw Sa counter-clockwise in the circular guide slot so far that the reverse switch just switches. Fasten screw Sa in this position.
f. Turn frequency scale pointer clockwise to the point of the higher frequency limit of scanning range.
g. Move screw Sb clockwise so far that the reverse switch just switches. Fasten screw Sb in this position.

The selected frequency range will now be scanned automatically in a forward and reverse direction if OPERATION SWITCH is set to "Scanning On".

5.3. Uni-directional Frequency Scanning.

Normally the automatic frequency scanning is performed as a series of forward/reverse scans and the scanning range is adjusted as described in section 5.2 above. However, in some cases it may be advantageous to scan the frequency range a number of times in one direction only. This is possible if the reverse-switch arm is removed. The arm can be easily unscrewed from the associated micro-switch by means of a screwdriver, see Fig. 5.1. If the arm is pushed to the right before it is unscrewed a continuous "forward" scanning of the frequency range is obtained, while pushing the arm to the left results in continuous "reverse" scanning. When used for continuous uni-directional scanning it is often necessary

to partially block the upper and/or lower part of the frequency scale range. The manipulations necessary to carry out the blocking are described below.

5.4. Partial Blocking of Frequency Scale Range.

The initial and/or the final part of the frequency scale can be blocked out by two adjustable cam discs. This facility can be utilized when the frequency scale pointer has to perform uni-directional scanning. Any initial part, 10 c/s up to 400 c/s of the scale, can be blocked, and/or any final part, 5ooo c/s down to 300 c/s.

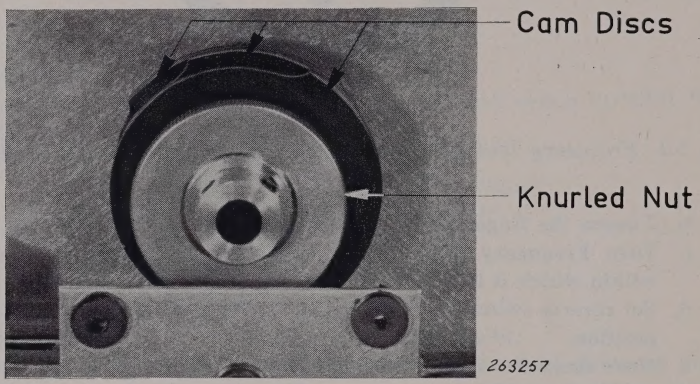


Fig. 5.2. Removing the back plate reveals some cams mounted at the rear of the tuning condenser. These cams are responsible for cutting the generator output while the pointer is in certain sectors of the frequency dial.

The blocking range is adjusted as follows:

a. Remove rear plate of apparatus.

b. Loosen knurled lock-nut (Fig. 5.2) sufficiently for the outer and inner cam discs to be moved in relation to the one in the middle.

NOTE: If it is not possible to hold the frequency pointer shaft in a fixed position by holding the frequency adjustment knob (front plate), the automatic scanning can be switched on and set to lowest speed.

c. Set, for example, outer cam disc for initial blocking so that the generator "Stand By" is released at the desired frequency. The point of release can be observed on the indicating meter when METER SWITCH is set to "Oscillator Voltage" and COMPRESSOR SPEED to "Off". (When released the meter pointer will suddenly deflect.)

d. Set the inner cam disc for final blocking so that the generator is switched to "Stand By" at the desired frequency. (Observed by a sudden fall in meter pointer deflection.)

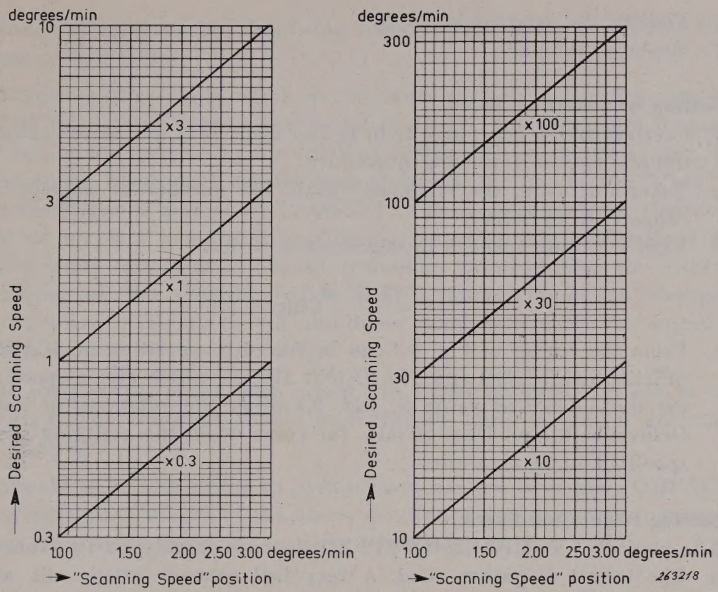


Fig. 5.3. Scanning speeds in degrees/minute given by the various combinations of SCANNING SPEED and SCANNING SPEED SELECTOR.

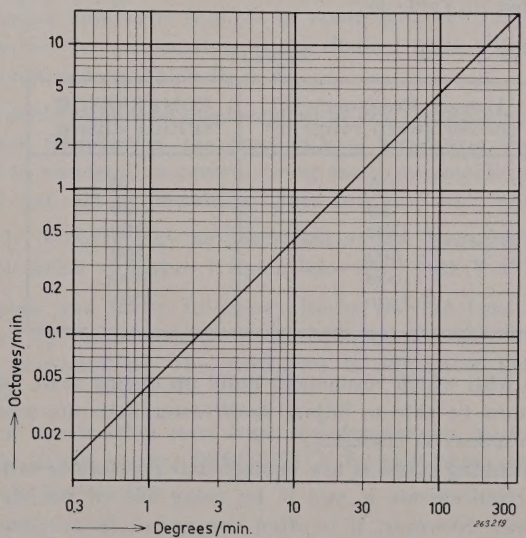


Fig. 5.4. Scanning speeds in degrees/minute converted into octaves/minute. Valid only for the 5—5000 c/s frequency range.

e. Tighten the knurled lock-nut.
f. Replace rear plate.

5.5. Setting of Scanning Speed.

If a certain frequency range f_1 to f_2 and back to f_1 has to be scanned in t minutes use the following procedure:

a. Determine from the frequency scale the number of degrees d the range f_1 to f_2 covers.
b. Find scanning speed S in degrees/min. from:

$$S = \frac{2 \times d}{t} \text{ degrees/min.}$$

c. From the curves in Fig. 5.3 can be found the position of SCANNING SPEED SELECTOR and SCANNING SPEED which give a speed nearest the calculated value S. Fig. 5.4 gives the relationship between Octaves/min. and Degrees/min. for cases when the scanning speed is specified in octaves/min.

5.6. Setting Regulation Speed.

The choice of COMPRESSOR SPEED depends largely on two factors:

a. The lowest frequency used. A very fast control system will, at low frequencies, be able to interact with the signal waveshape and thus introduces harmonic distortion. Consequently, if distortion must be minimized, COMPRESSOR SPEED should not be set to higher values than stated in Table IV.

Table IV.

Lowest Frequency of chosen sweep range c/s	COMPRESSOR SPEED dB/sec.
5	10
30	30
100	100
300	300
1ooo	1ooo
3ooo	3ooo

b. The rate with which resonances build up during scan. Obviously the system must be able to adjust itself faster than the mechanical frequency-response is changing.

When the scanning speed is low enough it is possible to satisfy both the conflicting requirements a. and b. by using one of the six fixed compressor speeds. However, it is often convenient in practice to use one of the four "auto" programmes so that the compressor speed changes with frequency, thus maintaining an optimum speed throughout the

range of interest. The following remarks may serve as a guide for the use of this facility:

When non-linear distortion in the order of 2 % is tolerable, the COMPRESSOR SPEED knob can be set to "Fast", the regulation time of the compressor then being the smallest obtainable on the generator. If the specimen resonances exhibit high Q-values, the use of the "Fast" compressor speeds may cause instability in the regulation loop. (Instabilities show up on a monitoring oscilloscope as amplitude modulations of the sine-wave test signal). Should instability occur during the sweep the setting of the COMPRESSOR SPEED knob should be changed to "Standard". The maximum non-linear distortion in the test signal then also reduces to less than 1 %.

If instabilities occur even when the COMPRESSOR SPEED is set to "Standard", the knob should be turned to "Med. Q" and if necessary to "High Q".

Should it be impossible to obtain good control with the COMPRESSOR SPEED knob in any of the above mentioned positions, it is necessary to utilize a fixed compressor speed condition, see item 5.6a.

5.7. Possibilities.

Either a velocity pick-up or an accelerometer may be used as the transducer sensing the motion of the shaker table. The Automatic Vibration Exciter control is capable of controlling the displacement, or the velocity, or the acceleration of the shaker table within the frequency limits indicated by Table II, p. 8.

It is possible to control displacement at low frequencies and acceleration at higher frequencies, the frequency of cross-over from displacement control to acceleration control being easily adjustable (section 5.8.) This kind of test will be known as "Auto D-A".

Similarly, velocity may be controlled at low frequencies, crossing over to acceleration at higher frequencies,—the "Auto V-A" facility.

The upper and lower frequency limits for the two "auto" cases are governed by the performance on displacement, velocity, or acceleration as the case may be. The cross-over is adjustable between 8 c/s and 1ooo c/s.

Constant acceleration tests from low frequencies up to 10ooo c/s must be made in two stages; FREQUENCY RANGE being switched manually before the second test.

5.8. Setting Auto Cross-Over Frequency.

Set OPERATION SWITCH to "Scanning Off".

Set FUNCTION SELECTOR to "Auto D—A or "Auto V—A".

Position the frequency pointer on the desired cross-over frequency. (Anywhere between 8 c/s and 1000 c/s is possible in principle). Hold the large tuning knob stationary and turn the small knob relative to it until the ACCEL. indicator lamp flickers, thus showing the position where operation is just passing to or from acceleration.

Sweep the pointer manually through cross-over and check that the transition point is correct. Fine adjust if necessary.

5.9. Summary of Preparatory Operations.

I. Calibrate the frequency scale (section 5.1.)

II. Set up the scanning range*) and speed required by the particular test specification. (Sections 5.2 to 5.5.) Having done this, leave OPERATION SWITCH on "Scanning Off".

III. If auto cross-over is to be employed, adjust the cross-over frequency to that required by the particular test specification (section 5.8 describes the method.)

IV. Set

DISPL. - VEL. LEVEL	fully anticlockwise ("0")
ACCEL. LEVEL	fully anticlockwise ("0")
OUTPUT VOLTAGE	fully anticlockwise ("0")

Frequency pointer to roughly the middle of the frequency range in use.

V. Connect the shaker table transducer to the 1019. When automatic cross-over is employed, both a velocity pick-up and an accelerometer may be used.

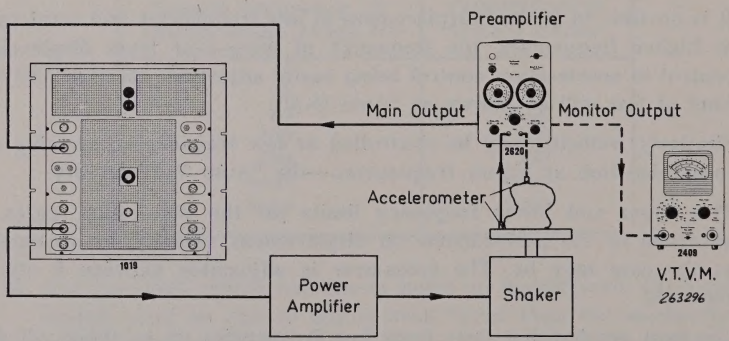


Fig. 5.5. Laboratory vibration-test system using an accelerometer as control transducer. Note the possibility of attaching a second accelerometer for monitoring the behaviour of the specimen.

*) Do not forget to position FREQUENCY RANGE correctly. Also check on Table II, p. 8, that the chosen range is admissible.

See sections 4.2 and 4.3 for full details; however, briefly the procedure is:

With accelerometer	*With vel. pick-up*
Signal to ACC. GEN.	Signal to VEL. GEN. INPUT
INPUT via preamplifier	VEL. GEN. RESPONSE to "Shaped" for MB/124 or 126

VI. Connect pins 1 and 2 of OUTPUT to a power amplifier and thence to the shaker; see the manuals for these two pieces of equipment. This completes the arrangement shown in either Fig. 5.5 or Fig. 5.6.

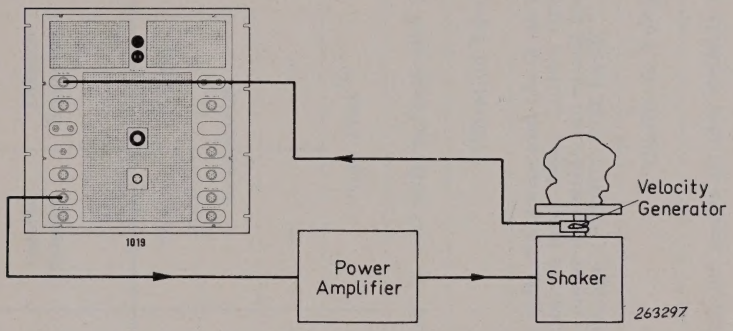


Fig. 5.6. Laboratory vibration test system using a velocity pick-up as transducer. Sometimes the velocity pick-up is a signal generator coil actually built into the shaker table.

5.10. Operation Schemes.

When the preparations outlined in section 5.9 have been completed, decide which of the five kinds of control enumerated along the top of Table V is wanted. Enter the table at the top of the appropriate column and work progressively downwards.

If in doubt about the meaning of the knob markings, refer to Chapter 3. To be sure that the levels are set up correctly, the working of the vibration derivation section must be properly understood; see Chapter 4.

TO STOP a test at any point, turn

OPERATION SWITCH to **"Stand By"**

Re-start the same test by returning
OPERATION SWITCH to "Scanning On".

This is particularly useful when changing specimens on the shaker table. To change from one kind of test to another, turn

OPERATION SWITCH	to "Stand By"
DISPL. - VEL. LEVEL	Anticlockwise ("0")
ACCEL. LEVEL	Anticlockwise ("0")
OUTPUT VOLTAGE	Anticlockwise ("0")
OPERATION SWITCH	"Scanning Off"

Then make new preparations (section 5.9 II. to V.) and follow the column in Table V relating to the next test.

Table V.

Operation Schemes for the possible constant vibration level tests.
N.B. Look through section 5.9 before proceeding further.

In order to maintain on the shaker table		**Constant Acceleration**	**Constant Velocity**	**Constant Displacement**	**Constant Displacement** below x-over **Constant Acceleration** above x-over	**Constant Velocity** below x-over **Constant Acceleration** above x-over
Object of each step	Set					
Choose vibration derivation	a) FUNCTION SELECTOR	"Acc."	"Vel."	"Displ."	"Auto D-A"	"Auto V-A"
Choose range given by spec.[1])	b) DISP. - VEL. RANGE[2])	—	As required		As required below x-over	
	c) ACCEL. RANGE[2])	As required	—	—	As required above x-over[3])	
Assist in equalizing L. F. response	d) OUTPUT SWITCH	"Lin."	"High Pass"		"High Pass"	
Set regulation speed	e) COMPRESSOR SPEED	Try "Standard" to start with, perhaps alter position later — see section 5.6				
"Open up" the generator, checking that vibrations are held down by control loop	f) METER SWITCH	"Vibration Level"				
	g) OUTPUT VOLTAGE	Turn slowly fully clockwise and check on meter scale that vibrations do not exceed desired level. Note: Correct functioning of regulation loop is indicated by meter deflection not rising above a certain small level even though OUTPUT VOLTAGE is further increased				
Reduce gain so that generator volts rise to useful level	h) METER SWITCH	"Oscillator Voltage"				
	j) OUTPUT VOLTAGE	Adjust until the meter pointer deflects to approximately half scale				
	k) Frequency pointer	—	—	—	Just below x-over	

cont'd. on page 34.

Set vibration levels[1] by adjusting feedback	l) METER SWITCH	"Vibration Level"			
	m) DISP. - VEL. LEVEL	—	Turn clockwise till vibration reaches required level		
Find excitation level just below x-over[3]	n) METER SWITCH	—	—	—	"Oscillator Volts", note meter reading[4]
	p) Frequency pointer	—	—	—	Just above x-over
Set vibr. levels[1]	q) ACCEL. LEVEL	Clockwise till required level	—	—	Adjust for same reading as in n[5]
Adjust gain so that gen. operates over optimum regulation characteristic	r) METER SWITCH	"Oscillator Voltage"			
	s) OUTPUT VOLTAGE	Adjust so that maximum meter deflection as frequency pointer is swept manually through—complete range used is 10 Volts[6]			
Check levels	t) METER SWITCH	"Vibration Level"			
	u) OPERATION SWITCH	"Scanning On". Observe one sweep. Trim LEVEL control(s) if necessary			
Check drive	v) METER SWITCH	"Oscillator Voltage". Re-check that 10 Volts is never exceeded. Trim OUTPUT VOLTAGE if necessary			
Test running	w) METER SWITCH	"Vibration Level". The test is now set up			

TO STOP a test, turn **OPERATION SWITCH** to **"Stand-By"**

NOTES:

1) Refer to the test specification which is to be followed by the operator.
2) Use left-hand positions when the signal originates from a velocity pick-up; right-hand positions for an accelerometer.
3) There should normally not be a jump in level on cross-over. Acceleration just above cross-over then corresponds to vibration level existing just below cross-over, in other words the excitation level will be the same both sides of cross-over.
4) If pointer should exceed full scale, adjust OUTPUT VOLTAGE till meter is readable.
5) If this is not possible it means that ACCEL. RANGE (item c) was badly chosen. Roughly compute the correct acceleration (see note 3) and reset RANGE.
6) Choose suitable Power Amplifier gain; this is complementary to OUTPUT VOLTAGE setting.

6. Operation with Level Recorder

6.1. Possibilities.

The frequency scan of the Automatic Vibration Exciter Control Type 1019 can be synchronized with the paper drive of the B & K Level Recorder, Type 2305. If frequency calibrated chart paper is used in the Level Recorder, direct plots of vibration levels (to a variety*) of logarithmic and linear scales) can be obtained against frequency. This convenient presentation of information is particulary useful for

A. Monitoring the motion of the shaker table (section 6.3)

B. Charting the combined frequency response of the power amplifier, shaker table and specimen (section 6.4)

C. Recording the vibration level of some part of the specimen, i.e. to measure resonances etc. (section 6.5).

6.2. Synchronization with Level Recorder.

Before measuring any of these vibration levels the frequency scanning system of the 1019 must be linked and synchronized with the paper drive of the Level Recorder. There are two possibilities;

either, I, the whole system can be started and stopped manually by turning the 1019's OPERATION SWITCH,

or, II, a single sweep can be initiated by pressing the SINGLE CHART button on the Level Recorder, the system then being stopped automatically after one chart has run off.

I. Manual Stop.

a) Insert roll of recording paper (QP 0123, QP 0423 or QP 1123) into Level Recorder. For details, see Instruction Manual for Type 2305.

b) On Automatic Vibration Exciter Control set
SCANNING SPEED SELECTOR to one of the six right hand side positions
OPERATION SWITCH "Scanning Off"

c) Unscrew Reversing Arm (see Fig. 5.1). For clockwise scanning, leave reversing switch in right-hand position and reduce "active" frequency range by means of camdiscs (see section 5.4) if required.

d) Interconnect Level Recorder's REMOTE CONTROL socket with the 1019's SWEEP CONTROL A. as illustrated in Fig. 6.1.

---

*) The dynamic range of Type 2305 depends on which special potentiometer is fitted to it. A 50 dB potentiometer is delivered as standard but the following are available: 10, 25, 50 or 75 dB logarithmic; 10 to 35 or 10 to 110 linear.

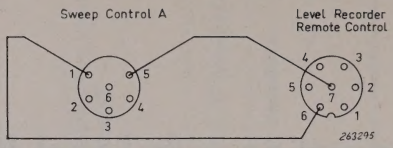


Fig. 6.1. To control the Level Recorder from the Automatic Vibration Exciter Control, connect the two instruments as shown here. Both sockets viewed externally.

e) On Level Recorder, set

PAPER DRIVE	"Start" and "Forward"
SINGLE CHART	In upper position
PAPER SPEED	See Table VI. Use the large figures around this knob

"Gear Lever X" (Button on right-hand end.) **Push in.**

Table VI.

Correlation between scanning speeds and paper speeds. The meaning of "pulse interval" will be clear from item k.

SCANNING SPEED SELECTOR position degrees/min.	o.864	2.59	8.64	25.9	86.4	259
Level Recorder PAPER SPEED mm/sec.	o.01	o.03	o.1	o.3	1	3
Pulse interval for 1019 drivemotor, millisecs.	50.00	16.67	5.000	55.54	16.66	5.554

POWER	"On"
MOTOR	"On"

f) Set frequency pointer of 1019 to frequency where scan and record should commence.

g) Adjust position of recording paper by Finger Wheel Z until pen covers frequency graduation corresponding to f).

h) Start scan and paper drive by switching 1019's OPERATION SWITCH to "Scanning On".

j) Stop at any point (less than one sweep or after several sweeps, as

required) by turning OPERATION SWITCH to "Scanning Off" or "Stand By".*)

k) Fine adjust 1019's scanning speed by the screwdriver operated Speed Trim control if required. (Located between the two SCANNING SPEED knobs). By trial and error it is possible to find a setting such that after a few sweeps the frequency pointer and the pen still agree. Alternatively, check, by means of an electronic counter that the 1019's sweep motor is being driven at exactly the right frequency. Connect the counter between chassis and pin 3 of SWEEP CONTROL B. Ideally the pulse repetition period seen here should be as given in

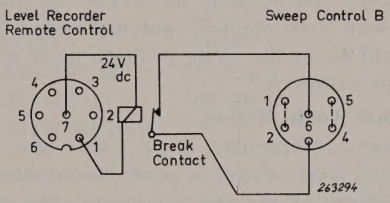


Fig. 6.2. If connected in this way, the system is started by pressing the SINGLE CHART button of the Level Recorder. Scanning stops automatically after one chart has been run off.

NOTE: Take out the interconnection (at the rear of the socket) between pins 3 and 6. The relay can, if convenient, be left coupled to the 1019 after the 7-pole plug has been removed from its socket on the Level Recorder; the 1019 is then in the same condition as when delivered.

Table VI. However, remember that the exact paper speed depends on the mains period and if this deviates from 20 msecs or 16.67 msecs**) the tabulated values must be adjusted accordingly.

II. Single Chart, Auto Stop.

m) Repeat items a), b) and c) above.

n) Following Fig. 6.2, connect Level Recorder's REMOTE CONTROL socket to a 24 V relay. A break contact on the relay then replaces a shorting link normally present on the back of the 1019's SWEEP CONTROL B socket. (Keep the other two shorting links, pins 1-2 and pins 4-5, in position).

---

*) Note: If several records are to be exactly superimposed, it is possible to run the system backwards by flicking the Reversing Switch on the 1019 to the left with a small screwdriver and moving the Level Recorder's PAPER DRIVE to "Reverse". Then stop and run forwards again. These controls must only be changed when OPERATION SWITCH is on "Scanning Off".

**) i.e. if the frequency deviates from 50 c/s or 60 c/s. (The Level Recorder gears can be arranged for operation at either 50 c/s or 60 c/s).

p) On Level Recorder, set

PAPER DRIVE	"Start" and "Forward"
SINGLE CHART	In upper position
PAPER SPEED	See Table VI. Use the small figures around this Knob
Gear Lever X	**Pull out.**
POWER	"On"
MOTOR	"On". Wait for paper to stop.

q) Repeat items f) and g).

r) Turn the 1019's OPERATION SWITCH to "Scanning On". Nothing should happen.

s) Start scan and paper drive by depressing the Level Recorder's SINGLE CHART pushbutton for a few seconds, then releasing it. When the scan has stopped automatically, the 1019's frequency pointer should be in the same position as it was initially.*) If it is not, follow procedure k.

6.3. Monitoring Shaker Table Motion.

This is not always informative, since either one or two straight lines are expected if the level control is good. Nevertheless it is useful to have indisputable evidence of the test conditions. The principle is simply to

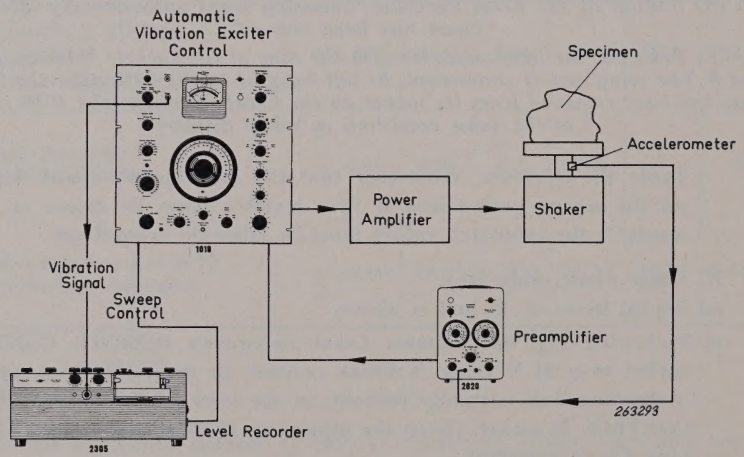


Fig. 6.3. Vibration test system coupled to a Level Recorder which plots vibration levels at the shaker table.

*) When superimposing similar recordings it may be useful to back-track the whole system. To do this, flick the Reversing Switch on the 1019 to the left with a screwdriver and move PAPER DRIVE to "Reverse". Press SINGLE CHART and wait till the paper is back at the starting point. Do not forget to return both direction controls before recording again.

run the test as described in Chapter 5 but to monitor and plot the vibration signal which is being used to control the shaker table.
The arrangement is as shown in Fig. 6.3.

I. Set Level Recorder's amplifying and writing system:

POTENTIOMETER RANGE	"Stand-by"
RANGE POTENTIOMETER	Insert correct one, 10 dB, 25 dB, 50 dB, 75 dB, 10/35 Lin, 10/110 Lin.
POTENTIOMETER RANGE	Set to correspond with above, viz.: "10", "25", "50", "80", "12", "16", respectively
LOWER LIMITING FREQUENCY	"10 c/s"
WRITING SPEED	"40/80"
RECTIFIER RESPONSE	"R.M.S."
INPUT ATTENUATOR	"60 dB"
INPUT POTENTIOMETER	"0"

II. Start Scan.

In manual control case by switching 1019's OPERATION SWITCH to "Scanning On".
In single chart auto stop case by pressing the Level Recorder's SINGLE CHART button.

III. Set Plotting Level.

During a trial run adjust INPUT ATTENUATOR and INPUT POTENTIOMETER so that the ordinates of the chart can be easily related to the 1019's meter scale. (N.B. METER SWITCH on "Vibration Level").

6.4. Plotting System Frequency Response.

It is sometimes interesting to chart the open loop frequency response of the system from Exciter Control output to shaker table. There are two ways of doing this:

I. Open Loop, Measuring Table Vibration.

For safety reasons, this method is **NOT RECOMMENDED.** However, with complicated systems it can be argued that it is necessary, in which case proceed as in Fig. 6.3.

NOTE: Increase OUTPUT VOLTAGE **extremely carefully** and watch the vibration level at all frequencies of interest to see that, even at resonance, no damage is done. Away from resonance frequencies, the vibration level will be very low.

II. Closed Loop, Inverse Characteristic.

Since the closed loop system always strives to maintain constant level at the shaker table, the inverse of the required characteristic is to be seen at the OSCILLATOR jack.

Therefore it is only necessary to set up the closed loop system under proper operating conditions using the same procedure as in section 6.3 but now to connect the OUTPUT socket*) at the back of the 1019 to the Level Recorder INPUT. A curve as that of Fig. 6.5 results.

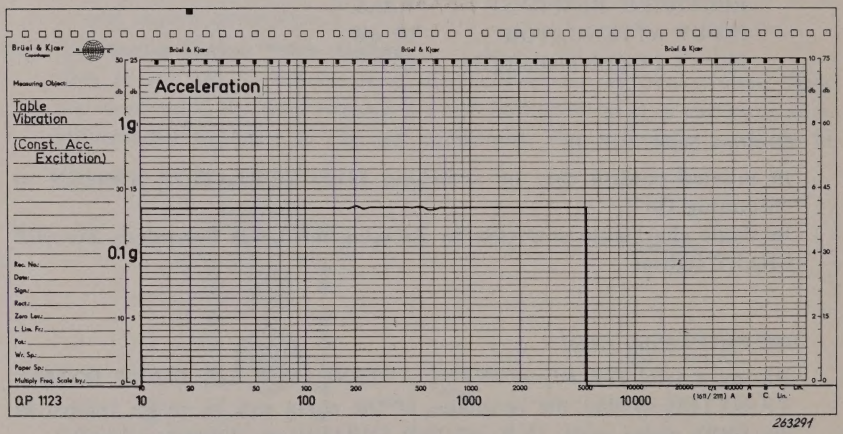


Fig. 6.4. Example of Level Recorder chart showing table vibration levels as a function of frequency. Constant acceleration control, 10 c/s to 5000 c/s.

*) Not the OSCILLATOR jack on the front panel since this should not be loaded by an impedance of less than 500 kΩ.

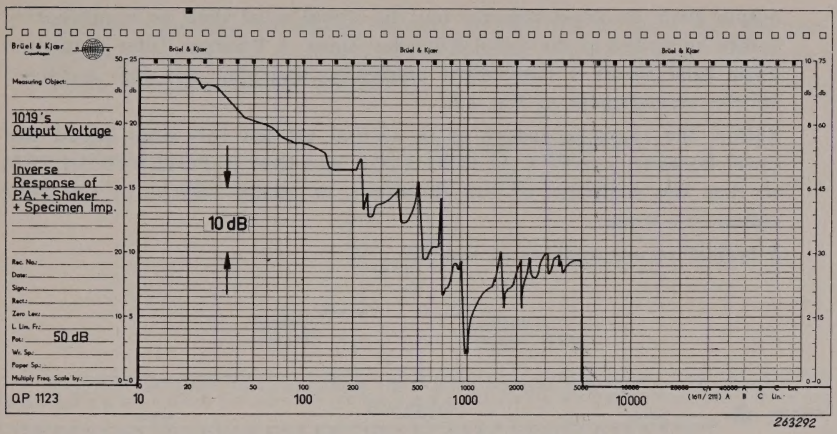


Fig. 6.5. Example of inverse characteristics of power amplifier plus shaker table. It is actually the voltage on the OUTPUT socket which is plotted here.

6.5. Recording Specimen Vibration.

The intention here is to record the resonances of the specimen so a second transducer is required. The monitor channel of the Type 2620 Accelerometer Preamplifier is ideal for matching and calibrating the

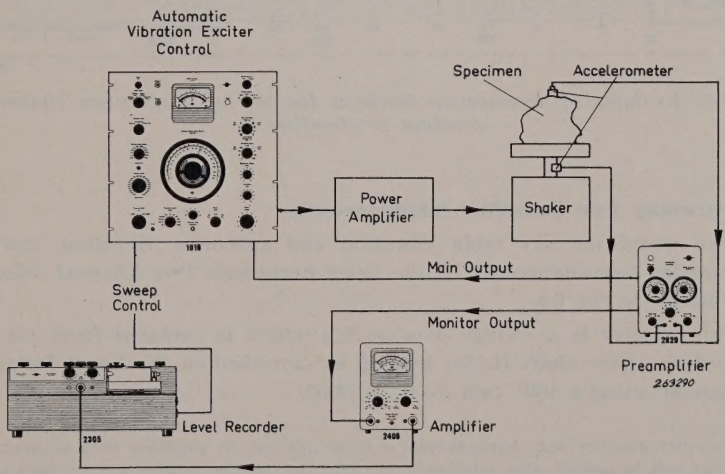


Fig. 6.6. Vibration test system in which the vibrations of the specimen are plotted on a Level Recorder.

output from an accelerometer but the signal must then be amplified**) before being fed to the Level Recorder input. A Vacuum Tube Voltmeter Type 2409 forms a convenient calibrated amplifier for this purpose; see the arrangement of Fig. 6.6.

Follow the same procedure as in section 6.3 but this time adjust the Level Recorder's INPUT ATTENUATOR and INPUT POTENTIOMETER so that the ordinates of the chart can be easily related to the 2409 voltmeter's scale.

A typical record appears in Fig. 6.7.

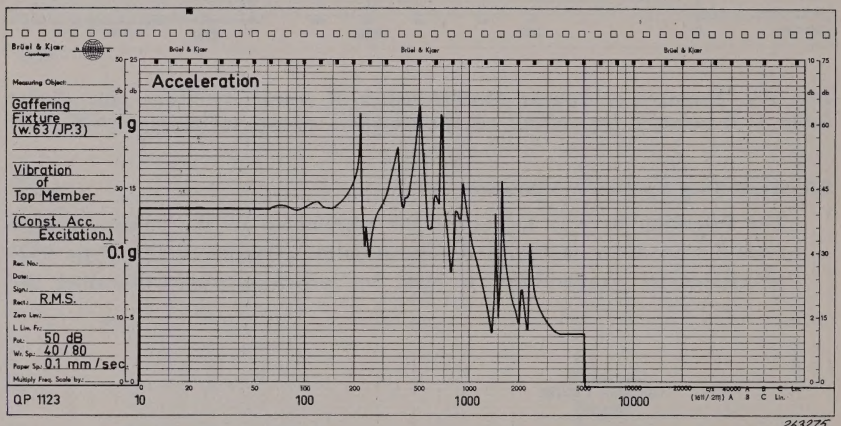


Fig. 6.7. Example of acceleration levels at the top of a specimen shaken at constant acceleration.

6.6. Recording Two Quantities Simultaneously.

Two quantities, say table vibration and specimen vibration, can be recorded "simultaneously" if the Level Recorder's Two Channel Selector is used, see Fig. 6.8.

This selector is a change over switch which is actuated from the recorder's Drive Shaft II. Set this up as described in the Level Recorder manual, using a 180° cam disc (OD 0059).

**) If another quantity (e.g. displacement) is to be derived, an amplifier with shaping networks will be needed. One solution is to route the monitor accelerometer direct to an Accelerometer Preamplifier Type 1606, which can perform one or two integrations. Type 1606 must be powered from, for instance, a Microphone Amplifier Type 2603. The latter also takes the place of the Voltmeter Type 2409.

Choose a position of DRIVE SHAFT SPEED R.P.M. such that the pen has time to take up position relative first to one signal and then to the other, still maintaining resolution.

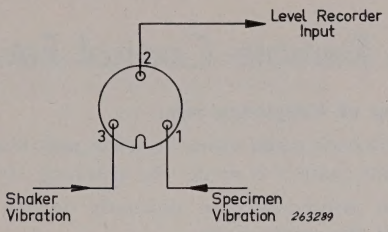


Fig. 6.8. Method of connecting the Two Channel Selector on the Level Recorder.

7. Remote Control Facilities

7.1. Start and Stop of Frequency Scan.

Connect a switch or pushbutton between pins 3 and 6 of SWEEP CONTROL B. When contact is made, the scanning system is operable.

Note: Remove interconnection normally across pins 3 and 6 of the socket. (Inside the instrument.)

This arrangement is utilized in one of the schemes for synchronizing the 1019 with a Level Recorder (Chapter 6.)

7.2. Forward and Reverse Frequency Scan.

a. Unscrew reverse-switch arm located in the frequency dial guide plate. (See Fig. 5.1.)

b. Set reverse-switch for anticlockwise scanning i.e. to its left hand position.

c. Connect a pushbutton between pins 2 and 3 of SWEEP CONTROL A.

d. Set OPERATION SWITCH to "Scanning On" position.
When operating the pushbutton i.e. closing the contact, the frequency scan will run forwards.

> **Warning.** If the reverse-switch arm is not removed, the scanning drive will be damaged as the scan is not reversed when the finger screw for the upper frequency-scan limit reaches the arm.

7.3. Stand by.

The stand-by facility can be remotely controlled when a switch or pushbutton is connected between pins 1 and 4 of RELAY CONTROL A. By closing the contact the generator is set to stand-by.

Note: The link soldered onto the back of the socket between pins 3 and 4 must remain.

7.4. Changing Scanning Speed.

Sometimes it may be useful to scan slowly through a resonance but rapidly through the rest of the frequency range.

Method I:

If the pulse repetition frequency of an external pulse generator can be suitably programmed, feed its signal*) onto pin 6 of SWEEP CONTROL B, having broken the link to pin 3.

Method II:

a. Set for the slower speed (through the resonance), one of the following settings of SCANNING SPEED MULTIPLIER:
"× o.3", "× 1", "× 3","o.864", "2.59", "8.64".

b. Wire up SWEEP CONTROL B as shown in Fig. 7.1.

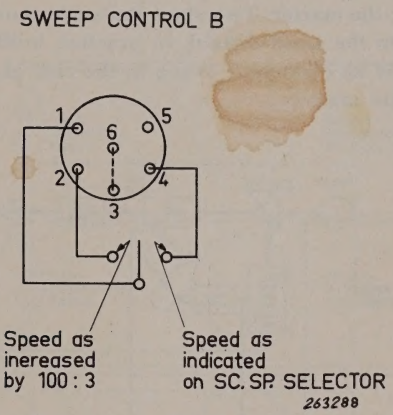


Fig. 7.1. How to increase the lower sweep speeds by a factor of 100 to 3. This is useful when "skipping" uninteresting parts of the frequency range. Note that the interconnections at the rear of the socket between pins 1 and 2 and between pins 4 and 5 must be removed.

c. Arrange, perhaps with a switch actuated by a tuning spindle extension, that the speed changes at suitable frequencies. The faster speed (through the uninteresting sectors) is 33 times the speed indicated by the knob settings. In other words, the change is equivalent to rotating the SCANNING SPEED MULTIPLIER three clicks clockwise.

*) Chassis negative, positive-going pulses of between 4 V and 10 V magnitude to pin 6.

8. Master-Slave System

8.1. Principle.

As explained in section 2.8, the outputs from all the Automatic Vibration Exciter Controls originate in the fixed and variable oscillator signals of the master unit. This is illustrated in Fig. 8.1, which also shows that the compressor loops are separate, though the compressor speeds are all switched by the master. Two slave units are shown but in principle there is no limit to the number used. In practice, however no more than three slaves should be connected owing to the risk of overloading the 6 V DC supply in the master.

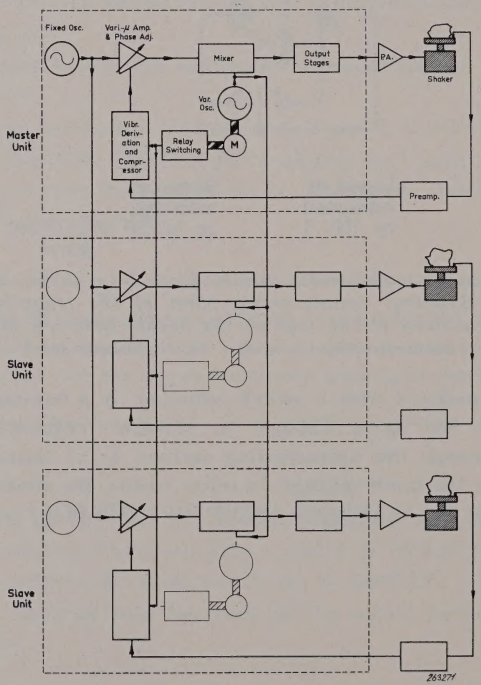


Fig. 8.1. Principle of operating several generators in parallel. Although the same frequency is fed to all shaker tables, the vibration levels can be individually adjusted.

8.2. Interconnections.

Wire up the individual systems as described in Chapter 5.

In addition, interconnect the sockets of the master and of the slaves as shown in Fig. 8.2.

Keep all the 1019 units close together. Each power amplifier must be fairly near to its associated shaker so if it is necessary to space out the shakers, the long leads should be those connecting the 1019's to the power amplifiers.

The high frequency potentials of the various chassis may not be exactly equal, so to prevent transients due to relay switching etc. from influencing the output signals, it is advisable to connect all the earthy

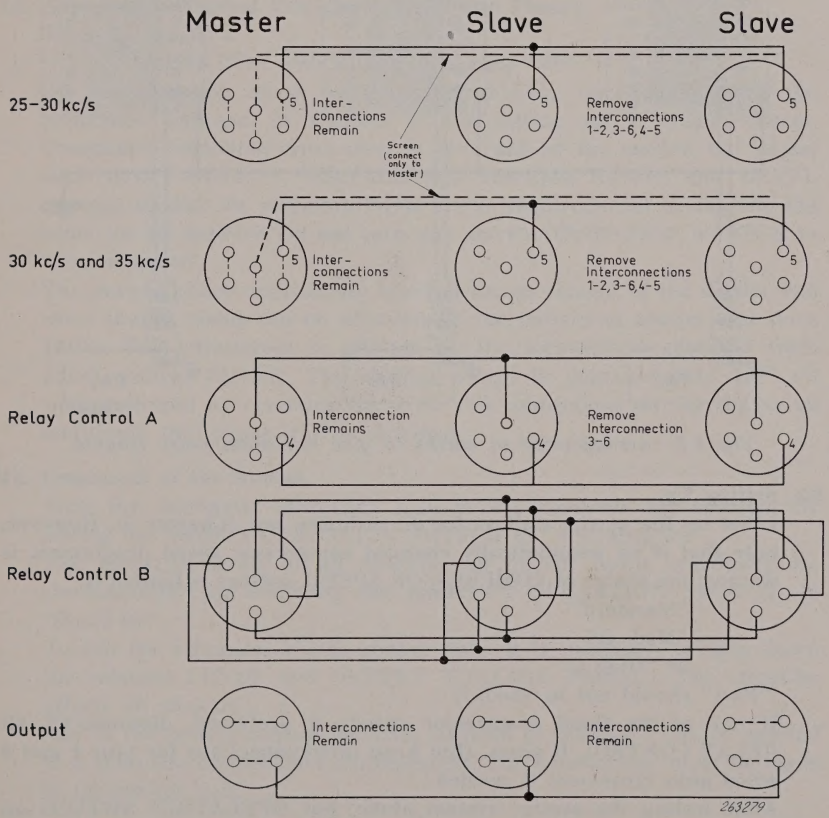


Fig. 8.2. Socket interconnections for "master-slave" system. (Viewed externally). NOTE: Connections shown are additional to the connections for the individual systems.

pins on the OUTPUT sockets together and take them to a good ground point. Use thick short wires.

It is usually advisable to directly earth the chassis of the power amplifiers. To prevent these earths forming a ground loop via the earth point mentioned above, the power amplifiers should each be fed through a transformer (Fig. 8.3.) Provided the transformers are located in close proximity to the P.A. inputs, ordinary inexpensive input transformers may be used; their frequency characteristic is not important since any peculiarities are regulated out by the system.

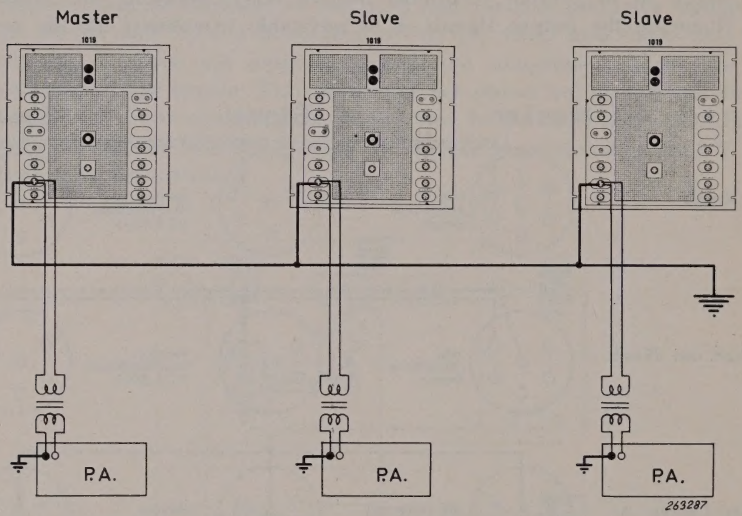


Fig. 8.3. Arrangement of earths to give minimum noise trouble.

8.3. Setting Up.

I. Set up the master unit as for an ordinary test (Chapter 5). However, note that if an automatically changed compressor speed programme is wanted, the choice of COMPRESSOR SPEED settings is limited to

"Standard"
"Med. Q"
or "High Q"

("Fast" should not be used).*)

If one of the fixed compressor speeds is preferred, disconnect*) all RELAY CONTROL B plugs. (But keep interconnections for pins 1 and 6 when auto cross-over is needed.)

After testing the master system alone, put OPERATION SWITCH on "Stand-by".

*) The reason is that ground loops would otherwise be formed by the various chassis earths and the relay control leads.

II. Set controls on all slaves.

OUTPUT VOLTAGE	Anticlockwise, 0"
OPERATION SWITCH	"Scanning Off"
COMPRESSOR SPEED	As used on the master
ACCELERATION LEVEL	Anticlockwise, 0"
DISPLACEMENT LEVEL	Anticlockwise, 0"
VEL. GEN. RESPONSE	As required

Frequency pointer to somewhere between 5 and 25 c/s on scale.
(Note: The pointer has to be placed within this range to avoid the compressor and cross-over relays being energized. The pointer can be locked in position by the Frequency Scanning Range stop screws.)
Cross-over point well above 25 c/s.

8.4. Adjusting Individual Vibrations (Level and Phase).

Turn the master's

OPERATION SWITCH to "Scanning Off"

Set the vibration levels on the slave shakers, once again using the principles outlined in Chapter 5 for setting up a single system. Frequency (including cross-over) is governed by the master, but adjust each slave's OUTPUT VOLTAGE and vibration RANGE and LEVEL controls so that the vibration levels are as required—not necessarily the same for all shakers. Do **not** turn any slave's OPERATION SWITCH to "Scanning On".

The desired phase relationship between the movement of the master and slave shaker tables can be adjusted on the individual master and slave 1019's. The adjustment is effected by the screwdriver operated front panel control PHASE. The shifting range is approximately 150° on each unit, and by reversing the drive coil connections on the shaker an additional 180° phase shift is obtained.

8.5. Command of the System.

Start the automatic frequency scan of the complete arrangement by setting the master's OPERATION SWITCH to "Scanning On".

The vibration levels of all shakers can be cut down practically instantaneously by switching **the master's***) OPERATION SWITCH, to "Stand-by".

To kill the vibration of one shaker only, it is necessary to turn down the relevant LEVEL and OUTPUT VOLTAGE controls. (The stand-by affects all shakers.)

Any of the remote control facilities outlined in Chapter 7 can be applied to a complete master-slave arrangement. The connections must be made to the master unit.

*) It appears possible to stand-by the whole system with any of the OPERATION SWITCHES. However, do not use this switch on any of the slaves because the stand-by relay circuit then becomes grounded at more than one point, thus causing hum problems (Hum about 50 dB below maximum output voltage.)

Specification

OSCILLATOR SECTION

Frequency Range:	5—5ooo c/s and 5—10 kc/s.
Frequency Scale:	Logarithmic from 5—5ooo c/s.
Frequency Accuracy:	1 % ± o.25 c/s.
Output Voltage:	Max. 10 Volts.
Max. Load:	10 kΩ/3 nF.
Output Voltage Characteristic:	Flat within ± o.5 decibel in the frequency range 5—5ooo c/s and within ± 1 decibel for frequencies between 5 and 10ooo c/s.
Monitor Output:	OSCILLATOR jack, load impedance to be greater than 500 kΩ.
Waveform:	Maximum distortion in the frequency range 5—10ooo c/s o.5 % without compressor. Maximum distortion with compressor o.5 % for higher frequencies, and 1 % for 10 c/s at the lowest compressor speed.
Hum Voltage:	At least 65 decibels below full output.

VIBRATION METER SECTION

1. Velocity Pick-up as Controlling Element.

Displacement Ranges:	Full scale readings o.01″ (o.025 cm), o.1″ (o.25 cm), 1″ (2.5 cm), and 10″ (25 cm), peak-to-peak value. Accuracy ± 4 % from 10—2ooo c/s. Approximately 4 % down at 5 c/s.
Acceleration Ranges:	Full scale readings 1 g, 10 g, 100 g, and 1ooo g (peak value). Accuracy ± 4 % from 10—2ooo c/s.
Velocity Ranges:	Full scale readings o.1 in./sec. (o.25 cm/sec.), 1 in./sec. (2.5 cm/sec.), 10 in./sec. (25 cm/sec.), and 100 in./sec. (250 cm/sec.), peak value. Accuracy ± 4 % from 5—2ooo c/s.
Pick-up Sensitivity:	The vibration meter is adjusted for a velocity pick-up output of 96.3 mV sec. per inch. (Peak-value volts and peak-value velocity).
Pick-up Impedance:	Maximum 2 kΩ.
Input Impedance:	Approximately 200 kΩ.

2. Accelerometer with Cathode Follower as Controlling Element.

Displacement Ranges: o.01″ (o.025 cm), peak-to-peak value. ± 4 % from 100 c/s to 2ooo c/s. Approximately 4 % down at 50 c/s.
o.1″ (o.25 cm), 1″ (2.5 cm), and 10″ (25 cm), peak-to-peak value, ± 4 % from 10—2ooo c/s. Approximately 4 % down at 5 c/s.

Velocity Ranges: o.1 in./sec. (o.25 cm/sec.). ± 4 % from 100 c/s to 2ooo c/s; approximately 4 % down at 50 c/s. 1 in./sec. (2.5 cm/sec.), 10 in./sec. (25 cm/sec.), 100 in./sec. (250 cm/sec.). ± 4 % from 10 c/s to 2ooo c/s; approximately 4 % down at 5 c/s.

Acceleration Ranges: Full scale readings 1 g, 10 g, 100 g, and 1ooo g (peak value). Accuracy ± 4 % from 10—10ooo c/s.

Pick-up Sensitivity: The vibration meter is adjusted for an accelerometer (preamplifier) output of 10 mV per g. (Peak-value volts and peak-value acceleration). The maximum allowable output impedance of the preamplifier is 1500 Ω.

Input Impedance: Approximately 80 kΩ.

Meter Scale: Semi-logarithmic.
Graduated: 0—10 (Volts, g, inches, inches/sec.).
0—25 (cm, cm/sec.).
— 10 to + 20 dB (decibels).

Monitor Output: VIBRATION jack. Load impedance preferably more than 10 kΩ. (70 kΩ series resistor built in).

COMPRESSOR SECTION

Frequency Range: 5—10ooo c/s.

Regulation Speeds: 10—30—100—300—1ooo and 3ooo dB/sec. Can be selected manually as a fixed speed for a complete frequency sweep, or automatically as a function of the oscillator frequency. "Switching" frequencies are: 10—100—300 and 1ooo c/s.

Dynamic Range: 60 dB, 20 dB can be compressed to o.5 dB and 40 dB can be compressed to 1.5 dB.

MISCELLANEOUS

Automatic Frequency Scanning: Built-in frequency sweep unit allows automatic scanning of any predetermined part of the frequency range. To-and-fro or uni-directional scanning.
132 different speeds. (o.3 degrees/min. to 335 de-

grees/min.), including six speeds enabling synchronization with the B & K Level Recorder Type 2305.

Frequency Limit Controls: Front-panel set screw adjustment, or partial blocking by means of built-in cam-discs.

Automatic Cross-over Control: Automatic Cross-over from Displ. to Acc, or from Vel. to Acc. at any frequency between 8 c/s and 1ooo c/s.

Stand-by: When Generator is set to stand-by the output voltage is suppressed by more than 70 dB relative to full output voltage.

Remote Control: Stand-by. Start-stop of automatic frequency scan. Forward-reverse changing of frequency scan. 33 to 1 scanning speed change.

Master-Slave System: Possible to run up to four units in parallel.

GENERAL

Overall Stability: Operates within stated tolerances for a mains voltage deviation of up to ± 10 %. Operable up to ± 15 % mains voltage deviation.

Power Supply: 115—127—150—220 and 240 Volts (± 10 %). 50 c/s to 400 c/s. Power consumption 80 W.

Tubes: 2 × 6AU6 (EF94) — 4 × 12AT7 (ECC81) — 1 × 12AU7 (ECC83) — 1 × 6BL8 (ECF80) — 1 × 6U8 (ECF82) — 1 × 6GW8 (EL86) — 1 × 12BY7 — 1 × OA2.

Semiconductor Devices: 2 × ASZ16, 1 × OC44, 4 × ACY20, 1 × 2N1671B.

Receptacles: Cannon, 7 × WK-6-32S, 2 × WK-4-33S, 2 × XLR-3-14. 2 Telephone Jacks.

The Automatic Vibration Exciter Control can be delivered either in a wooden cabinet (Type 1019) or for 19″ rack mounting as Type 1039.

Dimensions:

	Type 1019	Type 1039
Depth	34 cm (13.5 inches)	28 cm (11 inches)
Height	52 cm (20.5 inches)	48.5 cm (19 $\frac{7}{32}$ inches)
Width	51 cm (20 inches)	48 cm (19 inches)

Weight: 30 kg (63 lbs.).

Accessories Supplied: 1 power cord, 2 telephone jacks, 2 Cannon XLR3-11C plugs, 2 Cannon WK-4-21C plugs, 3 Cannon WK-6-21C plugs, various panel lamps and fuses.

Printed in Copenhagen, Denmark

June 1963